THE DEEP KANSAN PONDINGS IN PENNSYLVANIA AND THE DEPOSITS THEREIN.

PART ONE.

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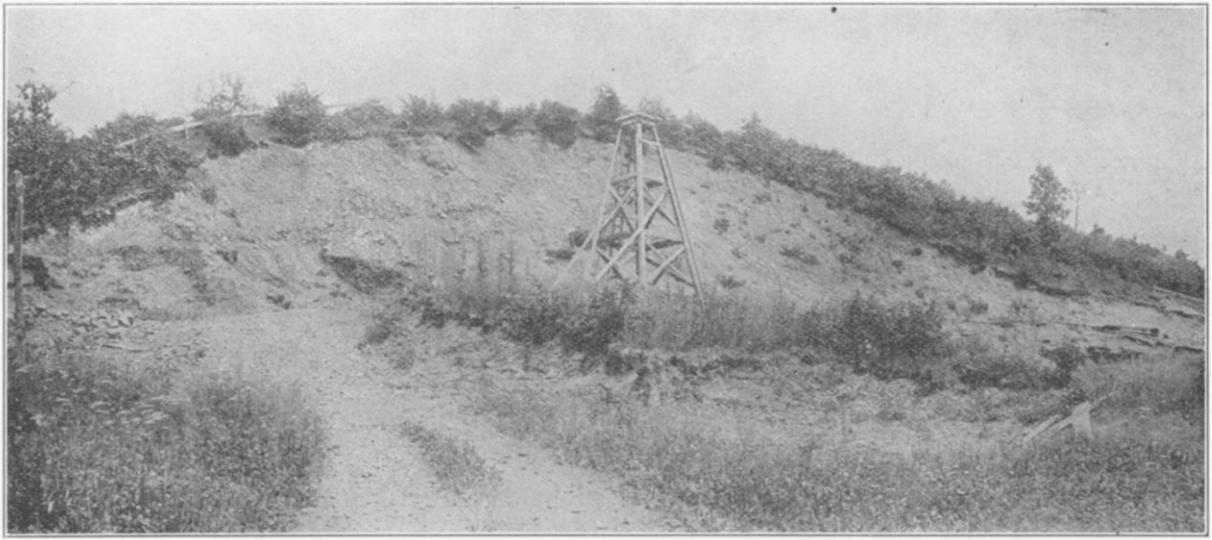
INTRODUCTION.

As the name "Kansan" is given to the drift in Pennsylvania, south of the moraine of Lewis & Wright, along the Allegheny River, and as it extends across the Delaware River from New Jersey, the intermediate drift in Pennsylvania south of the same will be so called, though it differs almost entirely in petrographic characteristics; as drift everywhere tends to conform to the outcrops on which it lies, and only in moraine or overwash accumulations is there a general and indiscriminate mixture.

It is proposed to-night to examine the character and the origin of the high-level gravels along Allegheny River, concerning which there is a difference of opinion. Other gravels will be used as illustrative material.

Professor G. F. Wright expressed the opinion in 1894[1] that some of the Allegheny gravels were remnants of a complete valley filling, since excavated; but he abandoned this theory later. In 1902 F. Leverett[2] expressed Wright's former opinion. Beginning in the Lehigh Valley, in 1892, E. H. Williams, Jr.,[3] found that the sculpturing of the Kansan outwashes antedated the deposition of the universal capping of iceberg silty clay. This is also the case in the Susquehanna and Allegheny valleys and is applicable to all foreset-bedded glacial outwashes deposited in deep pondings.

Pondings are of two kinds: those against a watershed, with gradually rising surface until a discharge over a col occurs and, if trenching occurs, with gradually diminishing depth: those against persistent or ephemeral ice-dams, with the depth varying with height of the dam. The former class is characterized by a permanence



SOUTHERN FACE, *Clarendon Gravels.* INDIAN HOLLOW.

which produces beach-lines—both filled and undercut—of good definition, high terraces with long and flat tops, and all the signs of long flooding: the latter will rarely persist at an exact level. We shall come upon good examples in this discussion, and when ice-dams occur in a valley like those of the Juniata or of the Allegheny, where there is a fall of the regional surface commensurate with that of the floodplain of the stream, it is evident that the height of the ice-dams would be similarly influenced, and the sporadic bars and terraces formed in the pondings would have a proportional fall in elevation, and of so marked a character that it would simulate the slope of a high gradation plain.

The illustrative material to be examined is found in the Hudson, Lehigh and Juniata valleys, whose streams were never reversed, and whose pondings were against ice-dams: in the Bald Eagle, and in an inconsequential part of the West Branch of Susquehanna River, between Williamsport and Lock Haven, both of which were temporarily reversed, and whose ponding was between the glacier and a col.

The Allegheny is a patchwork stream. It flows through 4 valleys in reverse, and through 4 trenched cols. There were many pondings with surfaces above 2,100 in the Pennsylvania Highlands; above 1,600; above 1,500; above 1,430, and above 1,200, as we proceed from those highlands to the mouth of Clarion River, where the crests of the region are 1,000 feet lower. The terraces, bars, sporadic areas of gravel of Kansan age partake of the elevation of the ponding, and fall in elevation, as will be seen below.

It is generally acknowledged that there was no sinking of the Kansan border in Pennsylvania during glacial times, and that the isobase of 200 feet crosses the Hudson Valley near Storm King Mountain. We can therefore use the Government and State Topographic Quadrangles to measure relative. elevations along that border, and, with proper corrections, elsewhere, during the period treated in this paper. The most of the illustrations which follow have been published before. The photographs were taken by the writer between September, 1892, and August, 1897. It remains to acknowledge his great indebtedness to the late Dr. Joseph Barrell who, as an assistant traversed the entire Kansan Border between the

Delaware and Allegheny rivers. Of the character of his work no encomium is necessary.

Storm King Mountain Ponding.

The Cambro-Ordovician rock floor of the Champlain-Hudson trough varies slightly on either side of the meridian until it approaches Kingston, N. Y., where it forks. The right-hand fork turns westward along a deflection of 20 degrees into the Cambro-Ordovician trough of the Rondout-Wallkill Valley, which is separated from a short valley in the same measures, leading to Delaware River, by a low saddle at 514 feet. Across this stream the Great Valley of Pennsylvania extends, in the same measures, to Maryland, with the highest point of its trough slightly below 500 feet. The left branch turns, at the same angle, eastward into a pocket through which Hudson River flows. The high eastern wall of this valley leaves its average of 16 miles from the stream and approaches it until, at Storm King Mountain, it rises 1,200 feet immediately from the stream edge. Marlboro Mountain forms an equally high wall on the west bank. The average valley width of 16 miles between the 500-foot contours, and of 32 miles between those of 1,000 feet, is constricted between these mountains, and at West Point is about $\frac{3}{5}$ of a mile wide at the lower, and 2 miles at the upper elevation. Similar widths at these levels along the Rondout-Wallkill Valley are from 2 to 6 for the lower, and 16 miles for the upper one. At the time of the depression of 200 feet, indicated by the above isobase, the above saddle still rose 314 feet above the then ocean level, and prevented a flow of water towards Delaware River, if the Storm King-West Point pocket were open.

Going north from the pocket we come suddenly, at Kingston, upon thick clean, horizontally-bedded brick-clay carrying infrequent good-sized boulders. Still further to the north the clay grows thin and sandy, with gradual change to foreset-bedded gravel dipping down stream, and in sporadic patches where sheltered from the current. The clay and boulders indicate a current of 2 inches, or less, per second; a depth of water sufficient to float icebergs so high above the deposit of clay as not to disturb its quiet and even deposition; a

stagnation in the pocket, and a high ice-dam as its cause. The gravels are found along the Rondout-Wallkill Valley, and indicate a current of 30 inches per second passing thence from the Hudson, and a depth of water—314 to 514 feet—sufficient to pass over its saddle.

Both clay and gravel are sorts of a glacial outwash. The cleanness of the former indicates a recession of the glacial front to the north sufficient to permit the separation of the sand and gravel sorts from the clay as soon as a slackening of the torrential current occurred. The volume of the torrent can be inferred from the fact that the Hudson Valley drained that part of the St. Lawrence basin which passed through Lake Champlain—all from the glacier and the region between the Green Mountain-Taconic range on the east and the Delaware-Susquehanna watershed on the west, and all from Central New York that did not escape south or west. Such a flood would clear away at once whatever deposits in the Hudson Valley were within the area of scour, as soon as the ice-dam in the pocket became weak.

This episode is an archetype of our periodic freshets, with their high water, their thin washes of slimes and of light trash, and their rapid subsidence. Nobody associates the distance between the high levels reached by the slimes, and the midsummer low water, to which they run continuously, as indicating the depth of excavation in a completely slime-filled valley. Nor do we so theorize about sporadic gravels dropped in deep pondings, such as will now be considered.

Delaware Narrows Ponding.

A similar ice-dam was formed south of Easton, Penna., in the Delaware Narrows, of bergs from the Hudson, and from the glacial lobe which crossed the former river north of Pocono Mountain. It ponded the Lehigh Valley up to 500 feet[3] during the wasting of the Hudson-Delaware-Schuylkill lobe there. As evidence of Arctic intrusion we find *Sedum rhodiola* growing on the side of the narrows where the sun never intrudes. This and Quoddy Head, Maine, are the two habitats of this plant in the United States.

The deposits in this ponding are sporadic. The most prominent

are long ridges of foreset-bedded gravels with infrequent cobbles and boulders, which extend towards the Delaware from the low hills or the projecting shoulders of South Mountain, which formed long areas of diminishing slackness. The bars thus diminish both in height and breadth as they near their ends. The lodging of bergs nearby made changes in the strength of the scour, and we find surfaces of erosion with unconformable beds on either side. This is especially the case at the end of the period when fine gravel was deposited, and the *Packer Clay* with its boulders and iceberg trash followed as a capping. Some of these bergs carried masses of rock weighing four and one half tons, and a heap of such masses were found on top of an eddy hill in what was South Bethlehem.

This clay capping is sandy and but 2 feet thick near lines of current of 5 inches per second; but is 30 feet thick and sand-poor in areas of still water. It lies unconformably over the ends of some of these long bars, and proves that their sculpturing preceded its deposition, and that they were never part of a complete valley filling since excavated. This latter was the theory of J. P. Lesley in his introduction, p. 37, to F. Prime's third report (D3, Second Geol. Surv. Pa., 1878), where he characterizes the Bethlehem gravels as "a high-flood river deposit, or an ancient high-level river-channel deposit."

Susquehanna Ponding.

This valley is so broad that the only places where damming took place in the Kansan Border are at the narrows near Rupert and at Little Mountain. The ice-dam in the former must have been above 160 feet high, as the Berwick upper sands reach that elevation, and carry glaciated cobbles and boulders.[4] At Nescopeck, opposite Berwick, E. H. Williams, Jr., reported[4] in 1895:

> There are three formations in the gravels at Berwick and Nescopeck: first, subglacial till so compact that a pick can scarcely be driven into it. This has a clay base and carries an abundance of rolled stones of all the formations to the north—even granite and anthracite meet in the mass. On this is a bed of modified drift of loose nature and sandy matrix with the same collection of rolled stones, and of equal freshness. In fact there is no difference in the color of the layers. . . . The lower inch of the gravels is a conglomerate with a limonite matrix, where the percolating waters laden with the solution of iron were stopped by the dense till below. Capping all is a layer of unstratified sand that varies in thickness greatly within a few feet, and carries streaks of gravel, glaciated cobbles and boulders at all levels.

This dam was in the narrower and more crooked North Branch of the river: the one in the main stream and far broader valley was low; but sufficient to form a terrace that runs, with slight rise, for 10 miles up the valley of Middle Creek, and for 20 miles up that of Penn's Creek. The latter has a delta 1 mile broad.[5] This low terrace is the nearest approach to a complete valley filling that we shall meet with.

Juniata Ponding.

I. C. White[6] was the first to describe the glacial outwash in Juniata Valley, and to call attention to the great distance above the average level of the gravel terrace to which sporadic patches of the same were carried. E. H. Williams, Jr., in 1895,[4] ascribed their origin to ice-dams in the many "Narrows" where this stream has cut through the more resisting ridges which border the trough-like valleys it crosses in its way to the Susquehanna River. The terrace runs with but slight rise far up the valleys of its affluents, and the sporadic gravels are the usual iceberg trash carried on the crest of the released wave when an ice-dam broke, and permitted the ponded water to rush up all opposing slopes and leave its bergs and their burden. This phenomenon occurs nearly every spring in northern

Fig. 1. Outwash from Lake Lesley, south of saddle, at East Tyrone.

New England streams when the winter ice is lifted by a freshet. Ice-dams are formed at each constriction and sharp bend of the valley, and water ponded to considerable depths, leaving gravel and boulders to be removed by the farmers before cultivation can be undertaken.

Figure 1 shows the character of the glacial outwash carried over the broad and flat saddle at Dix from the Bald Eagle to the Juniata Valley, and dropped at Tyrone as soon as the carrying current lost its velocity of 40 inches per second. The Juniata Valley was never touched by the glacier.

Bald Eagle Ponding.

When the Kansan lobe that moved down the North Branch of Susquehanna River touched the lofty wedge-end, where Bald Eagle and White Deer mountains meet and rise 1,200 feet above the flood plain of the West Branch of that stream, the water of that branch was ponded west of Williamsport, and the lowest point of discharge was the flat saddle at Dix, just above mentioned, into the Juniata Valley. This fixed the surface of ponding at 1,110 feet, and the depth against the glacier near Williamsport at 650 feet.

The gravels to be considered came from the wasting of that part

Fig. 2. End of ridge from Antis Gap, near Jersey Shore.

of the above lobe which had crossed Bald Eagle Mountain, and lay upon the several hopper-shaped valleys immediately south of it. The part of the lobe lying north of that mountain in the Susquehanna Valley between Williamsport and Lock Haven, and in the northern part of Bald Eagle Valley, had been cleared away by the torrent sweeping over the Dix saddle into the Juniata Valley, carrying icebergs and gravel, as just described. There was also a considerable discharge of the ponding through the marginal canyon between the glacier and the complex of ridges between Bald Eagle and Jacks mountains.

Figure 2 shows a sausage-shaped ridge of outwash from the wasting glacier in Mosquito Valley, formed by a narrow torrent sweeping through Antis Gap in Bald Eagle Mountain, and dropping its burden as its velocity was checked, and its course changed to that of the slow movement of the deep ponding towards Bald

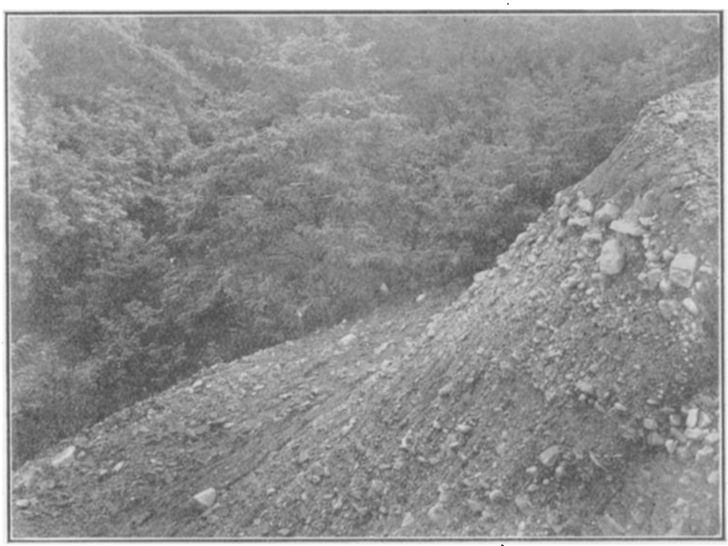


FIG. 3. Detail of cutting in ridge from Antis Gap, showing rough assortment of strata.

Eagle Valley. Mosquito Valley has a limestone floor and a high ridge-rim of Oneida. The gravel ridge is composed of these, and rises abruptly from the level Susquehanna Valley like an island from

a calm ocean, and bends up stream to show the above movement. It is so large that it has forced the river to make a loop 1 mile to the north of its straight course in order to pass around it, and a remnant exists near its former end as an island 1 mile long. Figure 3 shows the rough assortment of fresh Oneida sandstone and limestone in the dark and fully decayed preglacial surficial mantle of Mosquito Valley. Smaller ridges are found to the east, and opposite similar gaps in Bald Eagle Mountain, composed of similar materials from smaller hopper-shaped valleys. Excepting the most eastern, they bend up stream with the reversed current: the other bends down stream with the discharge through the marginal canyon. All have forced the Susquehanna to make loops to the north to pass around their ends.

The flood plain of this stream is here composed of rocks between the Lewistown limestone and the Pennsylvanian. It is evident that these ridges of entirely underlying measures are not part of a complete valley filling subsequently excavated; but are like the long ridges in the Lehigh Valley, dropped in deep ponding as soon as the velocity of the carrying torrent was sufficiently checked.

PART TWO.

Allegheny Pondings.

Introduction.

We note from what has been described above that ponding may be caused by stream reversal by glacial agencies, and by ice-dams. Permanent stream reversal is brought about by the trenching of the col or saddle in the watershed of the reversed stream to a depth sufficient to ensure the permanent discharge of the accumulated water after the wasting of the glacier which caused the original ponding. Secondary pondings, thereafter, are formed by bergs, as in the "Narrows" of the Delaware, the North Branch of the Susquehanna, and the Juniata.

Figure 4 follows Leverett's Fig. 1[2] in the arrangement of the three river systems that now make up the Allegheny River. Instead of "Old Upper," "Old Middle" and "Old Lower" Allegheny, these

systems are called Allegheny, Tionesta, and Clarion, from the prominent streams which compose them. Of these the last was the predominant stream in Western Pennsylvania. It rose on the plateau of the McKean County highlands in many good-sized feeders which almost met similar feeders of the Allegheny on the north side of the low slopes of the plateau. In the Pittsburgh area it received the waters of the Monongahela and Youghiogheny. Turning westward into the valley now occupied by the Beaver, it received the stream

FIG. 4. Map of Allegheny, Tionesta and Clarion Basins.

now reversed to form the upper part of the Ohio, and in the state of that name it occupied the valley of Grand River. It thus completely encircles the basin of the Tionesta-French Creek stream which partly to-day forms the Allegheny. In Fig. 4 only the portion from its sources to its junction with the latter is shown.

The black indexes mark the places where water was forced over watersheds by more or less deep ponding. Among these places are the four trenched cols: at Big Bend (connecting the Kinzua and Conewango branches of the preglacial Allegheny); at Thompson

(connecting the preglacial Allegheny and Tionesta); at Foster (connecting East Sandy and West Sandy creeks—branches of the Tionesta); at Emlenton (connecting the Tionesta and Clarion basins). The cutting of these to present stream level formed the modern Allegheny River.

An ephemeral connection between the preglacial Allegheny and Tionesta, and which has resulted in the piracy, by the latter, of the headwaters of the preglacial Conewango, occurred during the approach of the glacial margin towards Clarendon, when there was a discharge of the Conewango ponding over the Barnes col and trench into the Tionesta. There was also a trenched col at Titusville; but it had little or no influence in the formation of the gravels to be considered. Its elevation was 1,610.[5]

The following passes and cols enter more or less into the history of the ponding:[5]

A. On the Potter-McKean County Plateau. Discharges from Big Bend Ponding:

Keating Summit. Trench used by the Iroquois as a portage between the Allegheny and Sinnemahoning basins. Plateau top 2,400 feet; trench bottom 1,878 feet. Immediately east of the McKean County line.

Clermont. Broad shallow pass. Floor 2,068 feet. Allegheny discharge from Potato Creek through Mill Brook into East Branch of Clarion River.

Glad Run. Shallow pass. Floor below 2,100 feet. Into West Branch of Clarion River.

Kane. Forked pass, broad and shallow. The eastern fork into West Branch of Clarion River: the western, into the headwaters of the preglacial Conewango Creek; now, of the Tionesta. Floor 2,025 feet.

B. On the Allegheny-Tionesta Watershed. Discharges from Conewango Ponding:

Barnes. Trench. Top 1,500; bottom 1,300; filled with 2 terraces of gravel for 60 feet. Preglacial outlet into Tionesta River. Present outlet of preglacial branches of Conewango Creek, dammed by moraine at Clarendon, and now headwaters of Tionesta River.

Thompson. Trench. Elevation considered below. Outlet into Tionesta River after the arrival of the glacial margin at Clarendon.

C. On the Allegheny-preglacial Upper Oil Creek Watershed. Discharge from Conewango Ponding into Titusville Ponding. No cutting or trenching:

Torpedo. Pass. About 1,550 feet. Leads from Brokenstraw to present Oil Creek basins.

D. On the preglacial Upper-Lower Oil Creek Watershed. Discharge of Titusville Ponding:

Titusville. Trench. Top 1,610. Floor with gravel filling. Leads to Tionesta basin.

E. On the East-West Sandy Watershed. Discharge of East Sandy Ponding:

Foster. Trench. Top 1,500. Gravel filling of floor 900 feet. Leads to West Sandy basin.

F. On the Tionesta-Clarion Watershed. Discharge of Tionesta-West Sandy Ponding:

Emlenton. Trench. Top 1,450–1,480 feet. Floor with gravel filling to 860 feet. Leads into a short branch of Clarion River, probably Richey Run, 4½ miles above its preglacial mouth.

G. On Quaker Ridge, between the Conewango and Kinzua branches of Allegheny River. Discharges of Allegheny ponding as the glacial margin moved from the Conewango Valley up the spine of this ridge, parts of which now rise above 2,200 feet—all into the Conewango Ponding. From north of south.

Kennedy. This is the present filled channel of Conewango Creek at the debased end of Quaker Ridge. Top 1,250 feet. Rock floor probably 350 feet lower.

North Bone Run. Trench. Ridge-top about 2,000 feet. Floor 1,582 feet. A branch of the Kinzua, leading to Mud Run.

Bone Run. Trench. Ridge-top higher than last. Floor 1, 566 feet. Branch of the Kinzua, leading to Cass Run.

Storehouse Run. Shallow pass. Floor 1,925 feet. Leads to deep trench from the east bank of Conewango Creek.

Reynolds Run. Broad and swampy pass. Floor 2,020 feet. Leads to Ackley Run by trench cut below 1,500 feet for 2½ miles into the flank of Quaker Ridge.

Big Bend. Trench. Top 2,154 feet.[7] Floor probably 1,100 feet. Gravel filling to 1,200 feet. Sheer trench walls rise to 2,040 and 2,060 on opposite sides. The spine of ridge to west averages 2,100 feet. Leads to Conewango Ponding.

Of the above elevations, the only one concerning which there is a difference of opinion is at Thompson. Carll[7] says "at least 1,800," and Leverett,[2] "at least 1,220." The former is too high, as then the

Conewango ponding would have escaped through the Torpedo pass, as soon as the glacier at Clarendon had closed the way to Barnes, and the present Allegheny would now flow up the Brokenstraw Valley to Torpedo, thence through Grand Valley to Titusville, where it would occupy the lower Oil Creek Valley, and join the Tionesta at Oil City. The latter is too low as, with such an elevation, there never would have been a discharge at Barnes at 1,500 feet. Washes about Warren indicate that its elevation is about that of the col at Titusville, 1,610.

Pondings in the Allegheny Basin.

These can be separated into those which occurred during the advent of the glacial margin to Clarendon, and to the covering of the Potter-McKean Plateau, and those which occurred during the stagnation and wasting of the ice there. The Barnes and Big Bend pondings were in the former: that at Thompson, in the latter.

Barnes Ponding.

Elevation at beginning was 1,500 feet. Until the glacial margin touched the spine of Quaker Ridge, there was a free passage of all the ponding of the Allegheny Basin at the above elevation to the col at Barnes. The main current passed from the Allegheny up the Conewango to the col. The streams from the Brokenstraw Valley and the short valley with headwaters at Thompson came into the reversed Conewango at Warren, and prevented the distribution of any glacial outwash from the main stream west of Warren. In brief, there was no flow towards Thompson.

Just as the narrow torrents from the hopper-shaped valleys, through the gaps in Bald Eagle Mountain, left long and narrow ridges which rose from the level Susquehanna plain, and without a general distribution of their burden over that plain; so here, a current far broader moved up the Conewango Valley from the ponded Allegheny, and with increasing velocity as the glacier approached. At Warren it received the clear water from the Thompson-Brokenstraw region and passed by Glade, Clarendon, Tiona, Sheffield, to Barnes, where it escaped over the col. At Sheffield it received the stronger flow from the headwaters of the preglacial Conewango, re-

inforced at a later date by the torrent from the Big Bend ponding through the pass at Kane, noted above. We have thus a deposition of sorts of increasing size along this line of current, and only along it, from the Allegheny Valley to Tiona (in general), and Sheffield (with regard to some of the first deposits; but only in very thin beds). None of these deposits came to Barnes and thus into Tionesta River. Of these described by Williams,[5] the *Conewango Clay*, the *Upper* and the *Lower Indian Hollow Sands* were dropped during the discharge of the Conewango Ponding at Barnes, and the *Clarendon Gravels*, at the end—the moraines at Clarendon marking the arrival of the glacial margin of the main trunk on the Pennsylvania Highlands. All are glacial outwashes. Figs. 5 and 6 were

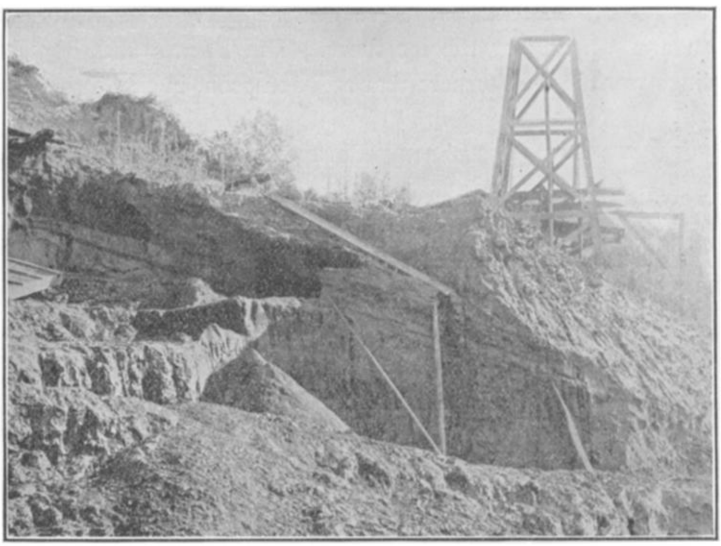


FIG. 5. *Lower Indian Hollow Sands*, east side.

taken from the same set-up, with the camera reversed. They represent the faces of a working in the *Lower Indian Hollow Sands:* the former looking eastward to the back of the Hollow; the latter, westward, toward the Conewango Valley. We are looking at the same strata. In Fig. 5 is shown an area undisturbed by the scour of the flow towards Barnes, though the regular dip of the foreset beds of different color in that direction shows that they were dropped in

deep water by a current moving to the Barnes col, and in quiet water, as shown by the uniform thickness of the beds. Fig. 6 shows a

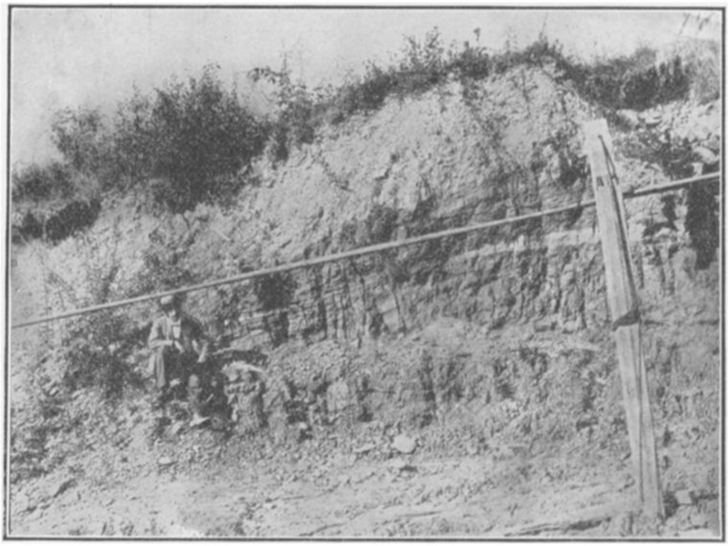


FIG. 6. *Lower Indian Hollow Sands,* west side.

westward extension of the same beds on the edge of the scour of the stream in the reversed Conewango, as each bed thins out, and sometimes completely disappears, as it is influenced by it. In fine, the strata were shaped at that time as we see them to-day, for this is no subsequent cutting down. Each bed becomes thinner, and the dip of the upper layers is steeper than of those at the base. Besides this, there can have been no sculpturing of these beds or of their surface since the deposition of the iceberg clay which is found—with varying degrees of sandiness or of silt—capping everything about Warren, and so down the Allegheny to Pittsburgh. At times the boulders in this cap are of large size, and speak of ice masses floating in deep ponding, as the deposit in which they occur is so uniformly composed of small sorts: at times it is clean silt with little or no larger sorts. Along the Conewango the *Lower Indian Hollow Sands* vary in thickness from 30 to 125 feet, depending upon the conditions of deposition in the different areas where it is found. It rests in the blued, sticky *Conewango Clay,* which carries wood fragments and logs, and is sometimes over 200 feet thick.

FIG. 7. *Clarendon Gravels* on *Upper Indian Hollow Sands.*

FIG. 8. Southwest face of *Clarendon Gravels.*

Fig. 7 shows the top of the *Upper Indian Hollow Sands,* horizontally bedded, and underlying the *Clarendon Gravels.* Such a deposition of coarse gravel with interbedded quicksand on sands could not have been made in an area of scour. This association, like the thinning out of the *lower sands,* just noted, indicates that the quiet area of Indian Hollow was crossed by a current of less than 8 inches per second; while at the surface of the ponding, 200 feet above, passed a current of over 30 inches per second, carrying the gravel.

Fig. 8 shows more of the southwest face of the working in the gravel bar. The sand stratum shows that the dip was the same as the average of the beds of the *lower sands,* and foreset in the direction of Barnes. The view of the houses of Warren, across the Conewango, in the left foreground, indicates the nearness of the bar to the valley trough, and that it is 200 feet, or more, above it.

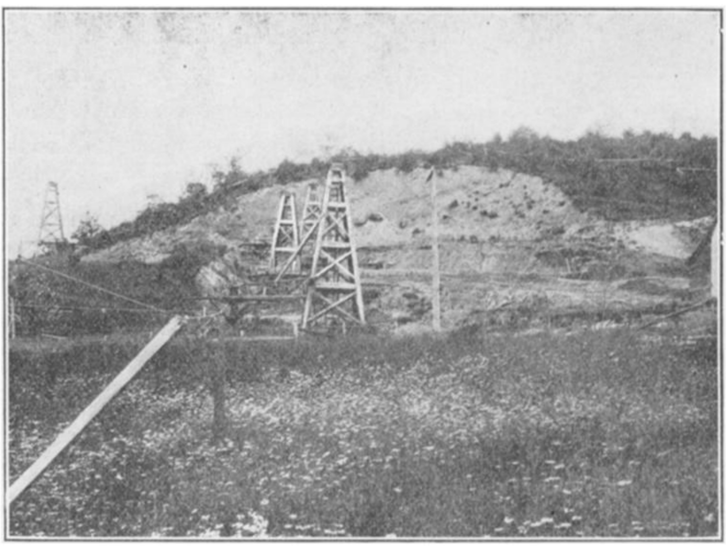


FIG. 9. *Clarendon* gravels on top of *Upper Indian Hollow Sands,* East Warren.

The southern face of the working in this bar is shown in the frontispiece and in Fig. 9. The oil-well rig in the former is the same shown on the extreme left of the latter, and in Fig. 5. This well, and the others in the Hollow, have given a comprehensive idea of

the shapes and thicknesses of the underlying sands and clay, and the depth and slope of the scoured rock floor as it dips toward and beneath the Conewango.

This bar originally stood above the level *upper sands* as do those in front of the Bald Eagle gaps. It stands away from the back of Indian Hollow, across which it originally ran. Its cross-section anywhere shows a cylindroidal surface with the sides coming down rather abruptly to the surface of the shoulder of the offshoot from Quaker Ridge behind which it was dropped, as shown in the frontispiece and in Fig. 8. Its crest merges with that shoulder at 1,488 feet, at a distance 2,300 feet up the slope, and 92 feet vertically above the top of the cutting shown in both figures. It is capped with iceberg clay.

As a further proof that these formations were dropped in deep ponding in sheltered areas along the line of current up the Conewango, and only along that line, we find a similar terrace-bar acros Glade Run Valley, since trenched by that stream, consisting of the same succession from *Conewango Clay* to *Clarendon Gravels*. Its axis points up the old Conewango, and toward Barnes, and its foreset dip has the same orientation. G. F. Wright, in 1914,[8] showed in his Fig. 2 a section of this bar 250 feet above the Allegheny River. This is in the shelter of the forked shoulder from Quaker Ridge which forms the southeast side of Indian Hollow, and is thus over the ridge from the bar above described. It has the same sand stratum near its top, and at about the same elevation; but as both bars are bedded with foreset strata, the plane of these interbedded sands at Glade passes in the air at least 1,000 feet above the similar bed at Indian Hollow. We find the same series at Stoneham and at Clarendon, and with the sand stratum near the surface at the latter place, dipping towards Barnes. They are thus not of a general valley filling afterwards sculptured to shape, as shown by the iceberg clap capping about Warren, which was not only dropped in deep water; but showed that the shaping antedated the drainage of the ponding. This last is also shown by the peculiar thin sheets of basal conglomerate with limonite matrix, as noted by Williams.[5]

Quaker Ridge Ponding.

This ponding began only when the margin of the main trunk of the Kansan glacier reached a part of the ridge-crest above 1,500 feet, and where there was no depression beyond below that elevation. It was therefore far later than the Barnes Ponding, as that began as soon as the old Allegheny Valley was dammed above that level, and until the glacier reached an elevation on Quaker Ridge also above that level, with no lower transverse troughs, the ponded water to the north of the Ridge poured through the troughs, at or but slightly above 1,500 feet.

It may be asked why no account is taken of the probable lowering of the Barnes trench, as its bottom to-day is at 1,300 feet. The reason is that the greater part of the cutting of that trench took place after the arrival of the glacial margin at Clarendon. It has been said that there are two gravel terraces in the Barnes trench. They consist of pieces of conglomerate, sandstone, red shale and shots of limonite—all local rocks from the McKean County highlands. In addition, it has just been stated that the Indian Hollow bar runs up to the surface of the shoulder of the hill at 1,488 feet. It is safe to say that the Barnes Ponding was not far below 1,500 feet when Quaker Ridge Ponding began.

The Conewango floodplain, at the debased end of the Ridge, is filled between 1,260 and 1,280 feet for nearly 2 miles across the valley, and for about 5 miles along the stream. Two small islands rising 40 feet above the Barnes Ponding represented the Ridge-end. Randolph, Twp., N. Y., is situated at its northern end with a continuous barrier between the Kinzua and Conewango valleys above 1,700 feet; rising in spots above 1,800 feet at the northern end, and to 2,100 at the southern boundary of the township, across which runs the first of the trenches which relieved the ponding—that from North Bone Run to Mud Creek.

The axis of the trench is about Northwest. Its center rises to 1,582 feet, at a point 7¾ miles from the Conewango, and almost exactly on the boundary between Randolph and South Valley townships, N. Y. Its width at 1,600 feet is 260 feet; at 1,800, 1,900 feet. It is nearly 2 miles between the 1,500-foot contours, on a curve of

13,500 feet radius. The wall of the stoss (southern) side rises 520 feet in one third of a mile, and reaches 2,100 feet in a long hill of 4 miles between the 1,500-foot contours. Its southern side drops to the trench from Bone Run to Cass Run. The summit of the latter rises to 1,566 feet, with a length of 1¾ miles between the 1,500-foot contours. The two trenches are about 1 mile apart: the latter curving in an opposite direction from the former, with a direction mainly westward. Its width at 1,800 feet is the same as that of the northern one, and for over 1 mile its width at 2,000 feet is less than three fourths of a mile. Its steepest wall is where the southern side is crossed by the boundary line between Chautauqua and Cattaraugus counties. Its rise is 580 feet in 1,300.

Thence southward into Pennsylvania, through Warren to McKean County, the crest of Quaker Ridge falls below 2,000 feet only in two places, where narrow passes lead from the South Branch of Sawmill Run—the northern, to Frew's Run, with floor about 1,970; the southern, to Storehouse Run, floor about 1,925, leading to a considerable trench which opens on the Conewango floodplain just north of Ackley.

After the covering of these the ponded water escaped at many places over the somewhat irregular, but level, crest of the Ridge—all above 2,020 feet—and the streams were gathered into four main flows, which passed through the troughs of Jackson, Ackley, Hatch, and Glade runs. With such distribution of power the trenching is long and shallow, and of note only at the lower parts. The elevation of the ponding is now above 2,020 feet, and slightly over 500 feet above that from Barnes.

Big Bend Ponding.

The overprint on the topographic quadrangle of Olean, N. Y., in the envelope attached to the back cover of Leverett's Monograph,[2] seems to confirm Carll's[7] elevation of 2,154 feet. Small areas rising above it are marked "Driftless." Larger ones away from the scour of the marginal canyon against the north side of Mount Hermon, which also rise above it, are enclosed and marked "South Edge of Ice," "Glacial Boundary," and "Border of Glaciation."

H. L. Fairchild[9] describes ponding in the Genesee Valley forced by the glacial lobe up that area, over the Potter County Highlands, and to the southern border of McKean County, which reached even higher elevations. It poured into Allegheny Valley with more or less deep and broad trenching at 1,494, at 1,600, at 1,692, and at 2,068 feet, and over the Potter County Highlands at 2,174, at 2,228, and at 2,252 feet.

The Big Bend Ponding poured over the McKean County Highlands at many places, as can be noted from the proximity of the feeders of the Allegheny and the Clarion on that plateau—the headwaters of several being about 300 feet apart. The greatest delivery on the east was through the deep trench at Keating Summit with bottom at 1,878 feet into the Sinnemahoning. Torrents came across into the feeders of the Clarion, as will be noted below. A strong flow came into the headwaters of the old Conewango: sufficient to keep the flow from Warren to Barnes ponded between Clarendon and Sheffield, and to prevent the slightest bit of glacial outwash to pass over the Barnes col into the Tionesta River. The Keating trench, and passes at Clermont, Glad Run and Kane, have been described above. These were the most important; but there seems to have been a general movement across the plateau when the margin of the main trunk of the glacier reached Big Bend, and the Genesee-Sinnemahoning lobe closed the trench at Keating. Williams describes the results[5] in the bars, high terraces, and areas of sporadic gravels in the Sinnemahoning and Clarion basins, and, as at Clermont, even on the plateau. Carll[7] reports 43 feet of stratified glacial outwash in the headwaters of the West Branch of Clarion River. The floods seem to have carried ice-cakes, as we find boulders in the stratified gravels along the Instanter Branch of that stream.

It is Leverett, however, who describes, p. 129,[2] the tremendous trenching of these floods from Big Bend Ponding, with their great elevation:

> At the mouth of the Clarion a broad gradation plain comes in from this (Clarion) valley and continues down the Allegheny to its mouth. This has been trenched to a depth of about 200 feet below the level of the old rock floor. The trench or inner valley is usually about one half mile in width.

Fig. 10. North outcrop of Mammoth Bed, Morea, Pa.

though it increases to nearly a mile near the mouth of the stream. At the level of the gradation plan there is a general width of about 1 mile. This gradation plain is capped by a deposit of sand and gravel, with an average thickness of perhaps 40 feet, that serves to accentuate the terrace-like appearance, for it fills up small trenches that have been cut in the gradation plain prior to the gravel filling.

This statement, and the description of the preglacial Clarion above, prove that the Clarion was the preglacial dominant stream in Western Pennsylvania. The above trenching cut its rock floor so far below those of its affluents that they are strongly refreshed for a few miles from their mouths, and seem to leap into it. This applies also to the Allegheny. The recency of the Clarion trenching is indicated both by the freshness and steepness of its rock walls. Leverett concludes his description of this trench with the words:

It is hardly necessary to state that just above the level of this gradation plain the bluffs are far more worn and receding than in the inner or canyon valley lying below it.

This freshness of the Mississippian-Pennsylvanian measures along the Allegheny is paralleled in the denser outcrops of the same in the Anthracite basins—notably at Morea. Fig. 10 shows that the resistance of the anthracite bed is greater than that of the top rock, and Dr. Kiefer's analyses[5] tell that the carbon ratio (38.37) of the beautifully polished surface was the highest of all the samples: that samples taken 60 feet below the surface came next with 38.20, and the mealed anthracite, ground up by the ice and found directly against the polished surface and below 8 feet of gravelly drift, showed 11.05 and 11.18. This is vastly different from the "black dirt" of an unglaciated outcrop with its low ratio of 1.23. Dr. Barrell[5] reported, in strength tests:

Samples near the surface of North Crop are as strong, if not stronger, than those at a depth of 55 feet. Sample No. 3 taken 250 feet below surface was an especially hard, solid piece of coal, and gave fairly uniform results; but its average is not different from that of the more fissile samples taken at the North Crop.

This bears upon the finding of fresh pieces in the Kansan gravels, and especially of crystallines from the preglacial surface which were given the usual concentric shells of weathering before incorporation in the glacier; but which have been irregularly gla-

ciated, like the cobble under the arrow in Fig. 11, which has been cut on the right side until the fresh, white nucleus shows. These facts force us to choose between a slowness of rock decay since Kansan times that seems negligible, or a recency of that time; as

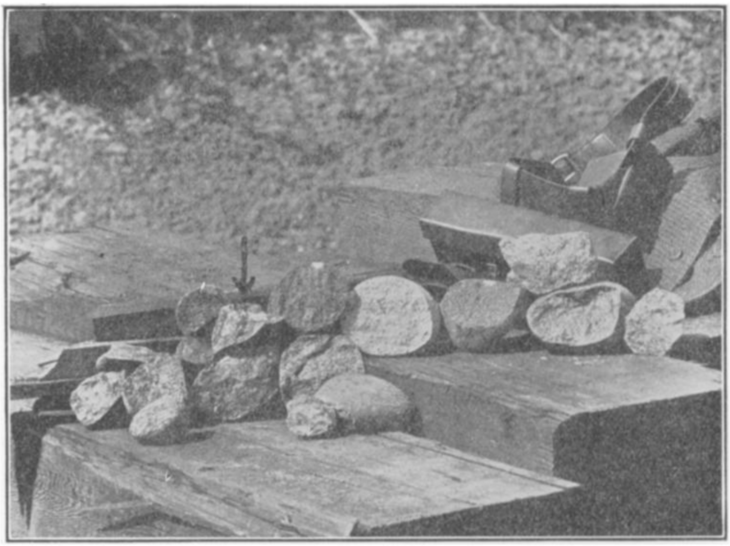


FIG. 11. Crystallines from South Warren terrace-bar, showing mixture of decayed and fresh pieces. Cobble under arrow has fresh (white) nucleus exposed by rolling.

the trenching of the Clarion and the deposit of these fresh rocks occurred when the glacier had spent its maximum strength in surmounting the Pennsylvania Highlands. Thereafter began its stagnation and wasting about Warren.

THOMPSON PONDING.

Elevation at beginning 1,610 feet. The glacial margin had spread over the entire Conewango Valley, and was over, or near Thompson col. Grand Valley and Titusville were covered. The water level about Warren rose over 100 feet, and into it tumbled the torrent at work excavating Big Bend Col which, at first, had a fall of over 650 feet, and, when the Thompson level was formed, continued with 500 feet of head. The glacial energy was gone and there was no more advance over the Highlands.

The torrential fall over Big Bend Col speedily tore a canyon through the stagnant ice in the Conewango Valley as directly as possible to the Thompson outlet: removed the deposit of *Conewango Clay, Upper and Lower Indian Hollow Sands,* and *Clarendon Gravels* from Glade to the mouth of Dutchman's Run (in the old Conewango channel), and the scour operated so far up the valley of the Run that it gave quickness to the sands in the formation at Stoneham, causing them to run out and the *Clarendon Gravels* there to drop on top of the *Conewango Clay.* Williams has shown[5] that the loss of the 100 feet of *Indian Hollow Sands* here, and so near the apex of the gravels at Clarendon, at 1,513.32, permitted a shifting of the latter towards Stoneham, and a dropping from their probable elevation of such a height above the crest of Thompson Col that they prevented a return to the Barnes discharge until the former col was trenched below 1,500.

In addition to opening a canyon through the stagnant ice in the Conewango Valley, the Big Bend torrent cut off 1,000 feet of the west end of the ridge between Morrison and Ott runs, and 1,500 feet to half a mile from the one between the latter and the old channel of Brokenstraw Creek, where it turned north to join the Cone-

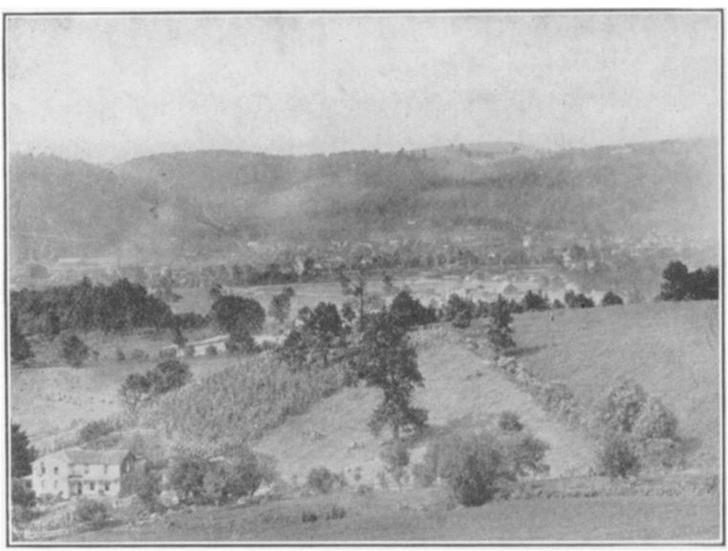


FIG. 12. *Early Big Bend gravels,* Oakland bar, South Warren.

wango.[5] The sheer walls of this cutting are shown along the railroad across the Allegheny from Glade. In this canyon were dropped some of the deposits described below, and others were dropped after the greater clearance of the glacier from the valley. Williams[5] has called these the *Early*, the *Middle*, and the *Late Big Bend Gravels* of the *Late Fluviatile Period,* as all the prominent deposits along the Allegheny Valley are associated with ponding, and with deposition by currents passing through stagnant water.

All of these deposits show foreset bedding dipping towards Thompson, and the earliest is the high, long, and narrow bar standing out into the level plain, on which Oakland Cemetery is situated, south of Warren and of the Allegheny River. This is similar in

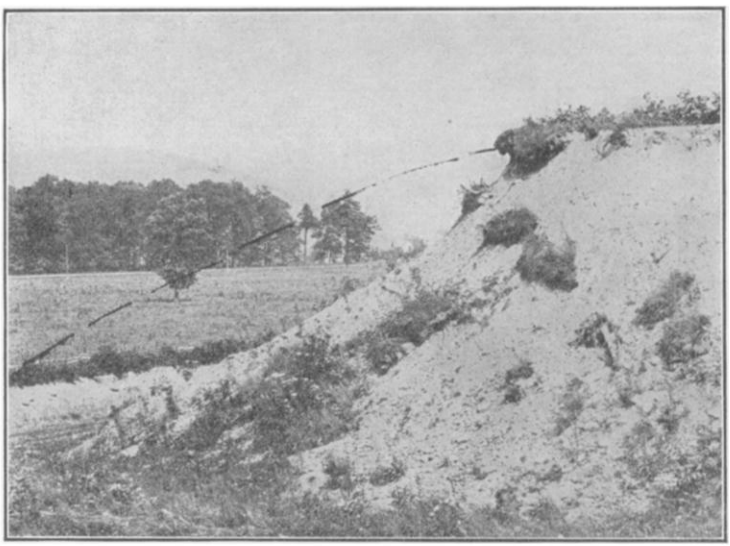


FIG. 13. Western end of South Warren terrace-bar, showing shaping before deposition of *Leverett* clay.

appearance and origin to the bars in front of the gaps in Bald Eagle Mountain (cf. Fig. 2). It is capped with iceberg clay, and its top has the elevation of the *Upper Indian Hollow Sands,* 1,322 feet. The old gravels in its composition are the *Clarendon Gravels* swept from the valley of Brown's Run, from the area where the Conewango channel was crossed by the torrent, and from that channel

for some distance towards Stoneham. They are smaller than the average of the pieces at Indian Hollow and at Clarendon, as would be the case after such rough rearrangement, and they are mixed with an equal proportion of local pieces eroded during the trenching described above. (Figure 12.)

Fig. 13 is the end of a bar composed of the *Middle* and the *Late Big Bend Gravels,* of lower elevation than the Oakland Cemetery bar. The worked-over crystallines in its composition are very much comminuted and among them are rocks foreign to the *Clarendon Gravels;* but found north of Big Bend. This indicates such a trenching of the col there that the scour reached to the Kinzua Creek bottom. There are also large pieces of local rocks—both old and fresh—which are absent from the older gravels. It is capped by iceberg clay, which is from 10 to 12 feet thick in places, and varies from a clayey matrix to nearly clean silt as it nears the end of this bar. The figure shows the dropping of the bar-end to the plain. This shaping and the decrease to one third of the thickness one half mile east, shows the increase in the scour of the current, as does the absence of the clay from the sandy cap. This latter was dropped after the shaping, and can be seen at the level of the plain across the country road. None of these Warren formations are remnants of a complete valley filling afterwards excavated. This closes the various pondings of the old Allegheny River.

Tionesta Pondings.

Emlenton-Foster Pondings.

Although the Emlenton Col is below that at Foster in the present Allegheny Valley, it was the first to be trenched. Its original elevation is inconsequential to this discussion, though it was below 1,500 feet, and probably between 1,430 and 1,480 feet, as shown by beach lines about, and north of Warren. It is on account of these, and of some sporadic gravels in the old West Sandy Valley that its elevation is a matter of interest.

Although the glacier crossed the mouth of the old Tionesta River ages before it reached Franklin, and though there was probably ponding in its valley from an early date, the discharge was

through a marginal canyon at a low elevation, and westward into the ponding of the old Clarion, as there is such a rapid westward slope of the region that only within twenty miles *below* Franklin, in the old Tionesta Valley, do its valley crests fall below 1,400 feet. Thus, though the ponded water may have been backed up the old West Sandy Valley against the Emlenton Col for thousands of years, with increasing depth, it did not flow over it until the glacial lobe passing down the western border of Pennsylvania had cut off the escape of the ponding at lower levels. As the side movement of a lobe-margin up hill is slow in comparison with the onward one of its front down or along a slope, it is safe to take even smaller figures for yearly progress than those suggested by Dr. Upham[10] at Toronto in 1913, and take 15 feet per year as the average progress of a margin constantly scoured by a torrent, and 20 miles from the mouth of old West Sandy Creek, as the position of the glacier when the flow over Emlenton Col began. The margin must move 22 miles to close that mouth, and with constant progress at the above speed would require over 7,000 years before the Tionesta Ponding would flow over Foster Col. As the trenching here is below present stream level, and the stream flows over gravel, it is evident that another long period intervened when the floods over Foster Col poured into West Sandy Valley and over Emlenton Col, and before the former col was fully trenched. We are now prepared to understand that, long before this happened, the Emlenton Col and the portion of West Sandy Valley between it and the Foster trench had been cut down to their present levels. And yet there was a ponding of the Tionesta against Emlenton Col after the Foster trench had been fully sunk. There was thus a first and second Emlenton Ponding, with the Foster Ponding as an episode between that reached far up the old Tionesta. With the first we have no concern.

Foster Ponding.

Elevation at beginning 1,500 feet. The trench walls on both sides rise to this elevation. Reddish iceberg clay with scanty gravel and cobbles is traced continuously to near this elevation on the hills about Franklin and at Oil City. Just below this mark where the country road from Franklin to Mays Mills dips down to Sandy

Creek in a sandy wash, there was found a cobble of red granite with quarry face and edges; but so pulverulent that it crumbled between the fingers. In the same wash were pebbles of fresh crystallines. These indicate deep ponding and floating ice. At Salamanca, Olean, and other places along the old Allegheny Valley are broad terraces at 1,500 feet. There are beach lines in the affluents of Kinzua Creek at this elevation, and indications of ponding at this level about Sheffield and Clarendon.

Second Emlenton Ponding.

The damming probably took place between this place and Foxburg, where the stream passes through the ridge with crests above 1,500 feet. The elevation of the water was between 1,430 and 1,480 feet, as shown by washes, beach-lines, etc., in the vicinity and at Oil City, Sheffield, and in some of the Kinzua affluents. At Roystone there is a swampy fan running from 1,430 to 1,480 feet.

Our study will be limited to the sporadic gravels in the West Sandy Creek Valley. These were thought to be remnants of a complete valley filling, since excavated, as stated by G. F. Wright in 1894.[1] This theory he abandoned—retaining however the idea of a complete valley trenching to the present rock floor before their deposition. Leverett, in 1902,[2] held the same view as to the trenching; but thought the gravels remnants of a complete filling.

There are three terraces of these gravels, and Leverett states:

> In several places, notably at the bends of the river at Brandon, at a point 2 miles below Brandon, at Kennerdell, at Black's (Winter Hill Station), and at Emlenton, there are deposits on the face of the gorge extending from the river's edge up to heights of 200 to 300 feet or more above the stream. The occurrence of this gravel at low places can not be accounted for by creeping or landslides, since in some places, notably at Kennerdell and 2 miles below Brandon, the gravels show clearly by their situation and bedding that they have not been disturbed since the stream deposited them.

The sole criticism is against the use of the word "gorge" for the low slopes on which the gravels lie at Brandon and at Kennerdell. At the former the slope varies from 7 degrees at one end to 16 degrees where it ends: at the latter the slope is 10 degrees. As would be the case when a torrent laden with glacial outwash trenches so tortuous a valley as that of West Sandy Creek, there would be

a working outwards on every curve, with the result of making the bends more pronounced, and of making a steep stoss-side against which the torrent would strike, and a low slope where scour did not obtain. These gravels lie on these low slopes where scour did not obtain during the trenching of the valley, and where it did not obtain when the far slower current dropped the sands and gravels that we are considering. Thus, though at Brandon and Kennerdell the gravel-covered slopes are at the above low angles, the opposite, or stoss sides of the valley rise almost from the stream edge at angles of 45 degrees at Brandon, and of 42 degrees at Kennerdell.

From the above quotation we learn that the gravels are sporadic and not continuous: that they have been disturbed by neither creep nor landslide since their deposition and, since they extend "from the river's edge," that the present channel was fully excavated before their formation. Their appearance at Emlenton tells us also that the col there was trenched to present stream level.

A consideration of the topography of the region is essential to the discussion. In the Brandon-Kennerdell area the 940-foot line crosses the Allegheny stream-level 1 mile from the western end of the trench at Foster, and the same distance west of Foster Station. There is a 50-foot terrace of gravel at Foster. The 920-foot line crosses the stream where Pine Hill Run enters the northern horn of the ox-bow bend above Kennerdell, and over 2 miles north of Kennerdell Station. At the Run mouth there is a steep stoss-side to the Allegheny Valley on the left, and against which the torrent strikes almost at right angles. This side rises from stream-level at an angle of 45 degrees, with but a slight shelf on which the railroad is built. The opposite side of the valley has the usual low slope, with a fine terrace, and a high bar like those above described. At the top of the steep stoss side there is a narrow level crest of the ridge about which the stream winds. The elevation is 1,400 feet for 2 miles from the end. From this runs downward the low slope on which the Kennerdell gravels are found. The 900-foot line crosses the stream 1 mile south of the southern horn of the Kennerdell ox-bow. The gravels at Brandon come down to the level of 930 feet; at Kennerdell, about to 914 feet.

The effect of the torrent from Foster upon the opposing valley

wall of West Sandy Creek, where a sharp ox-bow curve was made to turn it upon itself in order to pass to Emlenton, is seen in the great valley width, which is six times that at Kennerdell. With but slight narrowing this width extends southward to Brandon. If ponding obtained hereabouts it is evident that the velocity of the current through it must have been proportionally slower at Brandon than at Kennerdell. That there was ponding is shown by the classification of the pieces in the glacial outwash, and by the iceberg clay capping.

There are larger pieces in the Brandon gravel than in that at Kennerdell, and the silty cap at the former is 8 feet thick, against the 2 feet at the latter, measured at the same distance above the stream. The smaller sizes are also carried to a higher elevation at Brandon. The slower current there would produce a more profound slackness of the water in sheltered areas than at Kennerdell, and there would be less movement of the surface. It has been noted that the shoulder of the ridge which holds the Kennerdell gravels rises to 1,400 feet for 2 miles form its end. That which sheltered the area at Brandon rose slightly above an average of 1,450 feet, and in one place above 1,500 feet. The level of ponding was between 1,430 and 1,480 feet. The stream flowed through this along the broader channel above Brandon, and parallel to the axis of the ridge just described, which rose to or above the surface of the water. At Kennerdell, on the contrary, as the current swept about the bend where Pine Hill Run enters, it struck squarely against the stoss side of the ridge which shelters the Kennerdell area, and its upper 30 to 80 feet crossed that area directly. Only its profound depths would be suitable for deposition.

We are now prepared to appreciate why the coarse gravel extends at Brandon between 930 and 1,200 feet: at Kennerdell, between 915 and 1,000 feet. The fine gravel with 50 per cent. of silt, which tells of a slacker water, extends at Brandon between 1,200 and 1,300 feet: at Kennerdell, between 1,000 and 1,200 feet. The wave-action upon the thin drift sheet is marked at Brandon up to 1,400 feet; at Kennerdell all above 1,300 feet is swept away. Lastly, the iceberg silt, which caps everything, and which marks the slowness of the current at this end of the wasting of the Kan-

san glacier, is very sandy and, as stated above, is 8 feet thick at track level at Brandon; 2 feet thick at same level at Kennerdell. These two places are indicated on Fig. 4 by the blunt arrows opposite the letters (*ND*) in the name West Sandy Creek.

FIG. 14. Drift overlaid by assorted gravels, Brandon.

It is generally acknowledged that the glacial margin lay at or just east of the Allegheny Valley at these places. Figs. 14 and 15 were taken at track level, and thus at the same distance above stream level. The former shows drift overlaid by gravel at Brandon. The drift here is spared in the more sheltered area. The latter shows the entire thickness of the gravel at Kennerdell overlaid by the 2 feet of sandy iceberg capping.

These are no remnants of a complete valley filling. The only example of this exists in the abandoned part of the valley of West Sandy Creek between Polk and its mouth at Takitezy. Its highest point is near Niles, just below 1,160 feet. These gravels are like similar ones dropped in the quiet areas behind the protecting shoulders of ridges about which the stream winds. The only interesting point about them is that they seem to have been the expiring effort of the wasting Kansan glacier in the Allegheny-

Tionesta basins. When the ice-dam immediately below Emlenton was finally broken there was no renewal of ponding at such an elevation.

FIG. 15. Thinness of *Leverett* clay over assorted gravels, Kennerdell.

CLARION PONDING.

The margin of the Kansan glacier covered the mouth of Clarion River. The highest elevation of overwash gravel there is 1,230 feet; the highest point of the thin drift is at least up to 1,400 feet. In this are coal flakes carried above the outcrop, fresh fossiliferous Chemung, fresh black gneiss, and completely decayed basalt. The entire valley of the reconstructed Allegheny from its source to Foxburg was beneath Kansan ice.

The sporadic deposits in this ponding vary in elevation on either side of the stream at a given point, just as they do to the north. Opposite Indian Hollow, on the hill at Warren, there are no gravels of Kansan origin. At Tidioute there is 120 feet of difference in the gravel tops; at Foxburg, 100 feet.

There is also a difference in the character of the gravels on opposite sides of the stream. At Red Bank the west side shows a narrow

valley and a slope washed by the scour; more assortment of the gravel: not so many glaciated boulders of large size. The east side shows a wide valley and protection from current; more mixture of the gravel: many large glaciated boulders.

The ponding here was at least 200 feet below that above Emlenton, and high gravel ridges are found in the slack areas behind projecting shoulders of the high bluffs about which the current wound through the ponding. There are three such near Monterey, at varying elevations.

The iceberg clay is again the deciding factor. At the last named place it is 10 feet thick and with large boulders. The same are at Blairsville Intersection, at Red Bank Junction, at Fairmount, and they run to the tops of the ridges under conditions that show that they are not a subsequent wash. The Kiskiminetas Valley, and that of Red Bank Creek show terraces, bars, rock masses as large as a small house, in clay with boulders and local gravel of sorts, and all unite to tell of ponding in which Kansan gravels were dropped.

Conclusion.

The surface of Northwestern Pennsylvania resembles that of a flat and much etched cone, with axis at Kane, and a fall of 1,000 feet to Foxburg in 42 miles on a southwest course. The Kansan glacial margin spread southwestward about this apex and lay about in the meridian when it crossed the mouth of Clarion River. The passage of the lobe southward along the western border of Pennsylvania seems to have relaxed the activity of the portion capping the Highlands of the state. The discharge was along the marginal canyon between the glacier and the rising surface to the Alleghany uplift. This canyon rested at times across the watersheds at Big Bend, Thompson, Titusville, Foster and Emlenton, and induced such depth of trenching of cols that the subsequent ponding was able to complete the work.

The clearance of the region from the Kansan glacier began at the McKean-Potter Highlands in the Conewango Valley about Warren. The trenching of the canyon therein was accompanied by the settlement of the ice towards that valley trough, and the calving

of bergs into the torrent passing through. These grounded and packed wherever a chance offered, and there were many chances in so tortuous a valley. Pondings occurred after cols were degraded, and as a finishing clearance from the wasting glacier, the final ice-dams were comparatively feeble and against weak currents which brought the last of the washings of the thin drift sheet, and floated the remnants of the ice-cakes to form the clayey-sandy-silty capping which covers everything below the ponding level.

Because the ponding from the untrenched cols extends northward at high levels, and because we find this universal capping, it does not follow that the boulder clay was dropped everywhere at the same time. Its wide variations between clay, silt, and sand, as well as the great difference in size of the cobbles and boulders included, prove that in each portion of the Allegheny Valley it was merely the final episode of the clearance of that portion, and as the ice-dam at a given point was finally carried away, whatever ponding extended over that point was from a lower dam to the south.

This is proved to have been the case in the Allegheny Valley. The ice-dam just below Emlenton was not the sole one in that valley. Those to the north would be formed between walls reaching to a higher elevation: those to the south to a lower one. The sporadic deposits would be carried to elevations averaging above or below a theoretical gradation plain; but with wide variations therefrom on opposite sides of the valley at a given point that would not obtain in a complete valley filling. There is more adherence to such a gradation plain in the glacial outwash in the Juniata, as shown by the extension of the river terrace up the valleys of the affluents, and the strictness of the average elevation of 80 feet above present stream level. It is safe to conclude that the Kansan gravels in the valleys of the Lehigh, the Susquehanna, the Juniata, and the Allegheny were dropped and sealed in their present shapes during the final clearance from the Kansan glacier. There was no complete valley filling.

It seems also that this conclusion can be extended to gravels of uncertain or disputed origin in this and other countries. We have seen valleys never touched by the glacier, but adjacent thereto, and separated by a high watershed therefrom, invaded by torrential

flows which made deep trenches, and deposited stratified outwash and local gravels, as along the Juniata and the Clarion. It is permissible to ask whether these uncertain gravels, which are in unglaciated areas, but contiguous to possible glacial pondings, may not have had an origin similar to those under consideration.

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